R-F TRANSMITTER MODULAR SUB-ASSEMBLIES

Bi-Monthly Progress Report No. 4
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Prepared by
Engineering Department
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FIGURE

1. SUMMARY

This report covers the fourth bi-monthly period of the engineering program. It reviews the progress made during this period, and reveals the plans for the coming period. Included are sections describing basic module rf and modulator circuits, electro-mechanical components, and systems under development. Schematic diagrams and photographs of basic modular components and systems are illustrated.

2. INTRODUCTION

The purposes of this program are threefold. Namely, to produce a set of the "smallest practical" size basic modules, a similar set of modules in a cylindrical configuration, and a set of plug-together adaptors for the A1 modules. It appears likely that the total number of basic modules per set will be 18. Of this total 13 are rf modules, and 5 are af modules. By choosing combinations of these modules it will be possible to assemble 18 systems which will cover the frequency range 3 to 30 Mc; provide either 1/2 Watt or 5 Watts of CW rf power at the antenna terminals; allow a choice of A1, A2, or A3 emission; and insure proper operation into any antenna load in the impedance range 40 ± j40 (jx can be jo) to 1200 ± j 1200 (jx can be jo). Each basic module has solder type feed-through terminals in its enclosure for all interconnecting signal and power leads. Controls are held to a minimum for simplicity in tuning. All adjustments are made with a small screwdriver. Circuits are designed around transistors whenever the state of the art allows. Wisely chosen and thoroughly tested components are used to result in small size, high reliability, and satisfactory performance. Ferrites are applied considerably in rf circuits to obtain miniaturization without sacrificing performance. Epoxy glass printed circuit base plates are used to provide good electrical and environmental characteristics, ruggedness, and ease of reproduction.

3. PROJECT STATUS

The status of the project at the end of this period is outlined as follows:

A) Completed Circuit Design and Development

1) 3 to 7.5 Mc rf oscillator
2) 3 to 7.5 Mc rf amplifier for the 1/2 Watt systems.
3) 3 to 7.5 Mc rf amplifier for the 5 Watt systems.
4) 3 to 6 Mc antenna coupler
5) Microphone amplifier
6) 1 kc oscillator
7) 5 Watt system plate modulator.

B) Completed Circuit Design, Incompleted Development

1) 7.5 to 15 Mc rf oscillator
2) 7.5 to 15 Mc rf amplifier for the 1/2 Watt systems.
3) 15 to 30 Mc doubler-amplifier for the 1/2 Watt systems.
4) 7.5 to 15 Mc rf amplifier for the 5 Watt systems.
5) 15 to 30 Mc rf amplifier for the 5 Watt systems.
6) 5 to 10 Mc antenna coupler
7) 9 to 16 Mc antenna coupler
8) 15 to 30 Mc antenna coupler
9) antenna loading indicator
10) 1/2 Watt system plate modulator
11) processing module circuits

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C) Completed experimental model modules

1) 3 to 7.5 Mc rf oscillator

2) 3 to 7.5 Mc rf amplifier for the 1/2 Watt systems.

3) 3 to 7.5 Mc amplifier for the 5 Watt systems.

4) 3 to 6 Mc antenna coupler

5) microphone amplifier

6) 1 kc oscillator

7) 15 to 30 Mc doubler-amplifier for the 1/2 Watt systems.

D) The balance of the circuits listed in sections A) and B) of this outline are in the process of being packaged in basic module form.

E) Preliminary packaging design has been started on the plug-together and cylindrical module forms.

F) Operating electrical and temperature tests have been performed on several modules listed in Section A of this outline.

G) All essential large scale evaluation of commercial components has been completed.

H) The design and development of electro-mechanical components has been completed.

4. BASIC MODULE DESIGN AND DEVELOPMENT

4.1 RF Circuits

4.1.1 Crystal Controlled rf Oscillators

4.1.1.1 3 Mc to 7.5 Mc Oscillator

The 3 to 7.5 Mc oscillator design remains as previously reported. It is shown in Fig. 1.

4.1.1.2 7.5 Mc to 15 Mc Oscillator

The 7.5 to 15 Mc oscillator as shown in Fig. 2 is very similar to the 3 to 7.5 Mc oscillator. The major difference being in the output transformer. The 7.5 to 15 Mc circuit uses an auto-transformer as compared to the dual winding transformer used in the 3 to 7.5 Mc circuit. The input and output power characteristics are quite similar to those listed in Fig. 1 for the lower frequency range.

4.1.2 Power Amplifiers for the 1/2 Watt Systems

4.1.2.1 3 Mc to 7.5 Mc Amplifier

This amplifier as shown in Fig. 3 has been converted from a fixed tuned broad-band circuit to one including a single tuning control. This change was deemed advisable to increase the power efficiency, and reduce the harmonic content of the output. Tuning is accomplished by adjusting a wide range capacitor in the plate tank. The tube has been changed from a 5902A to a 5639, and operation from class A to class B. The latter tube is more suitable for class B operation. Class B operation is used in preference to class A because the addition of tuning warrants it and there is sufficient power available to drive the tube. Toroidal core transformers are still applied in the input and output circuits. The input transformer is a broad band low Q type, whereas the output transformer is a high Q tunable type. A high impedance diode detector circuit has been added across the low impedance output winding to allow headset monitoring of A2 or A3 emission. With a +130 Vdc plate supply and approximately 15 mW of drive power this amplifier is capable of producing at least 0.75 watt across a 50 ohm resistive load over the frequency range of 3 Mc to 8 Mc. Its plate efficiency averages approximately 40% over this range.

4.1.2.2 7.5 Mc to 15 Mc Amplifier

This circuit has been designed and is being developed. Its dc circuit is the same as the 3 to 7.5 Mc amplifier. The only difference in the ac circuit will be in the design of the input and the output transformer networks. Referring to Fig. 3, its circuit will be the same except for C4, T1, T2, and L1. Performance will be comparable to the 3 to 7.5 Mc amplifier.

4.1.2.3 15 to 30 Mc Doubler-Amplifier

Fig. 4 is a revised schematic diagram of the doubler-amplifier which was previously reported. The major change that has been made is the addition of an input winding to T3. It was necessary to split the input into two bands to obtain satisfactory performance over the range of the module. The amplifier is neutralized to prevent self-oscillation. This circuit has been packaged into an experimental module. It is being performance tested and "debugged".

4.1.3 Antenna Couplers

4.1.3.1 General

The antenna coupler system to cover the 3 to 30 Mc range, and to match any impedance in the range 40 ± j 40 (jx can be jo) to 1200 ± j 1200 (jx can be jo) has been divided into four bands to insure coupling efficiencies greater than 70%. These four bands are 3 to 6 Mc, 5.5 to 10 Mc, 9 to 16 Mc, and 15 to 30 Mc. For the purpose of simplicity these bands are designated C1, C2, C3, and C4 respectively.

4.1.3.2 Coupler C1

A schematic diagram of C1 is shown in Fig. 5. Minor changes such as the reduction in the number of positions on the coarse tuning and loading controls have been made on this circuit since it was last reported in Report No. 2. It is being repackaged to reduce the size, to make it more reproducible, and to make it more easily adjustable. Recent tests have confirmed suspicions that the V.H.F. suppressor is not necessary over the 3 to 6 Mc range; therefore it will not be included in coupler C1.

4.1.3.3 Couplers C2, C3, and C4

Couplers C2, C3, and C4 have been designed. They are in the development and model packaging stage. These will include the V.H.F. suppressor, and will probably be identical physically.

4.1.4 Power Amplifiers for the 5 Watt Systems

The 5 Watt system amplifier utilizing 2 ceramic metal tubes that was described in Report No. 3 has been abandoned because of the extremely high price of the ceramic tubes. Its successor is shown in Fig. 6. It is a conventional class "C" power amplifier using a low cost commercial beam power pentode type 6417. The input and output transformers are toroidal core types. The grid and plate tanks are capacity tuned. Neutralization is used to prevent self-oscillation. When driven by the output from the 1/2 Watt system amplifier and with a plate supply of 260 Vdc, this amplifier is capable of delivering approximately 8 watts to a 50 ohm resistive load from 3 Mc to 7.5 Mc. Its plate efficiency averages approximately 50 per cent over this range. An experimental model of this circuit has been packaged and is being evaluated.

An amplifier using a smaller premium type 5686 tube has been designed and compared performance wise with the 6417 amplifier. Under similar operating conditions it is capable of producing only 6 watts to a 50 ohm resistive load from 3 Mc to 7.5 Mc. It is felt that the use of this tube is not warranted since the power delivered to a load through the coupler would be much less than the specified 5 watt output.

The 7.5 to 15 Mc and 15 to 30 Mc amplifiers will be designed around the 6417.

4.1.5 Antenna Loading Indicator

A device to indicate antenna current is to be provided. A search for a method better than an incandescent bulb shunted by a suitable switch has been conducted.

Early investigations were aimed at incorporating an extremely small meter as a tuning indicator. Presently available 1 inch meters were found to be unsuitable because of their size. To design and develop a much smaller meter (1/2 inch) would have required an expenditure of approximately $15,000.00. Since a meter was not considered the most reliable device for this purpose, an extensive search was made for a smaller, cheaper, and more reliable type of indicator. This search resulted in the design and development of the circuit of Fig. 7. The tuning indicator is a type DM70 sub-miniature triode with a fluorescent anode that glows in the shape of an exclamation point when the electron beam bombards it. The length of the light bar increases as the plate current increases. The DM70 features extreme sensitivity, clean and highly accurate visual indication, low filament consumption, small size, and long life.

A brief analysis of the loading indicator circuit follows. The lead connecting the antenna coupler output to the antenna terminal is fed through the center (against the core) of a broad band toroidal inductor. An rf voltage which is proportional to the magnitude of the rf current in this lead is induced in the inductor. This voltage is essentially constant over the frequency range 3 to 30 Mc. The induced rf voltage is rectified and regulated by diodes CR2 and CR1. Regulation is necessary so the indicator can be used on either the 1/2 watt or 5 watt systems. The rf current range in the 5 watt system is much greater than the 1/2 watt system current range; therefore regulation is used to prevent transistor Q1 from saturating with 5 watt currents. If it was allowed to saturate no further indication in antenna current change would be indicated. Transistor stage Q1 is a dc amplifier whose collector voltage controls the plate current of the indicator tube. R5 and R6 are filament dropping resistors. The voltage developed across R6 is also used to bias the indicator tube so a wider range of control can be obtained.

The degree of accuracy of this loading indicator is comparable to that of a VTVM measuring the rf voltage directly across the transmitter load.

Tube type 6977 can be substituted for the DM70 in this indicator with minor circuit changes. It is much smaller in size, but it is not as accurate because tuning is accomplished by a change in light output rather than a change in light bar length.

An experimental model packaged indicator with the DM70 has been built, and placed in operation. It measures 1 13/16" x 1 1/16" x 1/2".

4.2 Modulator Circuits

4.2.1 1 kc Oscillator

This circuit as shown in Fig. 8 has been adjusted for optimum performance. It has been performance tested and temperature tested. An approval model has been packaged and tested.

4.2.2 Microphone Pre-Amplifier

The microphone amplifier as reported previously has gone through a repackaging phase to reduce its size. This required a considerable number of changes in large capacitor values. These changes were made without radically changing its electrical characteristics. The present amplifier circuit appears in Fig. 9. Considerable use of solid tantalum capacitors has been made to reduce the module size. An approval model is being packaged and tested.

4.2.3 Processing Module

The processing module circuit includes the clipper-filter, two buffer amplifiers, and a modulator pre-driver amplifier. Minor adjustments have been made to the clipper-filter. The pre-driver has been incorporated to provide sufficient amplification of the microphone amplifier and 1 kc oscillator signals to drive the 1/2 watt system modulator. An approval model is being packaged and tested.

4.2.4 Modulator Amplifier for the 1/2 Watt Systems

This amplifier design has been changed radically from the one reported previously. A class "B" push-pull circuit designed around expensive silicon transistors was reported last period. Since that time the circuit of Fig. 11 has been designed and developed. It is a conventional type class A amplifier (with temperature compensation) designed around an inexpensive germanium transistor. Its performance compares quite favorably with that of the push-pull amplifier. Performance testing is continuing on this circuit and an approval model is being packaged.

4.2.5 Power Amplifier for the 5 Watt Systems

A 5 watt system modulation amplifier was described in Report No. 2. Since that time modulation techniques other than the plate type have been investigated with the goal being a reduction in the size of this module. Thus far no means has been found to reduce the size appreciably, and still obtain high performance with respect to modulation index, frequency response, and distortion.

5. ELECTRO-MECHANICAL DESIGN AND DEVELOPMENT

5.1 Miniature Hand Key

The miniature hand key is in production for the final systems.

5.2 Miniature Variable Capacitors

The design and development of these components has been completed. A small and a large value variable capacitor have been developed especially for this project. Their ranges are nominally 5 to 100 uuf and 10 to 250 uuf. The variation in capacitance is accomplished by changing the parallel spacing of two metallic plates with a very thin dielectric between them. Originally 1/2 mil teflon tape was used as the dielectric material. It was replaced eventually with 1 mil mica for several reasons. The teflon required very careful handling, and too much time to place it properly on the fixed plate of the capacitor. In addition it had to be kept perfectly clean before, during, and after its placement in the capacitor. Several failures occurred in operation when the plates were driven together, and dirt punctured the teflon. With the plate supply on the fixed plate when used in a plate tank, the voltage arced across the 1/2 mil gap through the puncture and immediately developed a short to ground. Numerous capacitors using mica as a dielectric have been incorporated in experimental models, and no troubles have been encountered during their assembly or usage. It is felt that these capacitors are ready for production, and that they will prove to be very valuable and highly reliable components.

The dimensions of the 10 to 250 uuf capacitor when completely covered with a teflon tape and silicon rubber dirt and moisture seal are 1 1/8" x 2 9/32" x 11/32". The 5 to 100 uuf capacitor is approximately 7/8" x 3/4" x 11/32".

5.3 Miniature Rotary Switch

The design and development of this component has been completed. This 12 position single pole switch is used in the antenna coupler modules for switching inductors and capacitors. It is designed to possess low rf loss and low stray capacitance characteristics. The switch contact plate is an epoxy glass etched board. The front mounting plate is also made from epoxy glass. The detent plate and shaft are made by International Instruments, Inc. All contact and wiper surfaces are gold plated. The final switch assemblies will be sealed with a silicon rubber dust and moisture cover.

5.4 Dual Control Concentric Shaft Switch

The design and development of this component has been completed. It was designed especially for coarse tuning of the Cl coupler. The switch plate is an epoxy glass doubleclad etched board with two concentric sets of contacts; the outside set having 16 contacts, and the inside set having 14 contacts. The wipers are screwdriver controlled by a pair of concentric shafts. The switch housing serves as the supporting structure for the entire contents of the Cl coupler. All contact and wiper surfaces are gold plated for high rf conductivity, anti-corrosive properties, and low contact resistance vs. life.

6. SYSTEMS DESIGN AND DEVELOPMENT

6.1 General

The number of systems necessary to meet the requirements of the contract are tabulated below in code form according to type of emission, power output, and frequency coverage:

SYSTEM NO	FREQUENCY BAND 1 = 3 to 7.5 Mc 2 = 7.5 to 15 MC 3 = 15 to 30 Mc	EMISSION TYPE	POWER OUTPUT WATTS
I	1	A1	1/2
II	2	A1	1/2
III	3	A1	1/2
IV	1	A1	5
V	2	A1	5
VI	3	A1	5
VII	1	A2	1/2
VIII	2	A2	1/2
IX	3	A2	1/2
X	1	A2	5
XI	2	A2	5
XII	3	A2	5
XIII	1	A3	1/2
XIV	2	A3	1/2
XV	3	A3	1/2
XVI	1	A3	5
XVII	2	A3	5
XVIII	3	A3	5

A modular breakdown of these systems will be given in the future. As of this date either 17 or 18 modules including the loading indicator will be furnished to make up the 18 systems in the table. Fig. 5 is a schematic diagram of the 1-A1-1/2 system. It is being evaluated at present.

Figs. 12, 13, 14, and 15 are photographs displaying the 3 to 7.5 Mc rf section for the 1/2 Watt or 5 Watt systems, and the modulator section for the 1/2 Watt systems. Figs. 12, and 14 show the contents of each basic module.

7. PLANS FOR THE FUTURE PERIOD

It is hoped to complete the development of the circuits listed in section 3. B, and the construction of at least one experimental basic module of the entire group of circuits. Systems development will be continued with these models.

The plug-together and cylindrical packaging design and development will be continued. The miniature key production will be completed.

Specification testing of the 1-A1-1/2, 1-A2-1/2, and 1-A3-1/2 model systems should be completed.

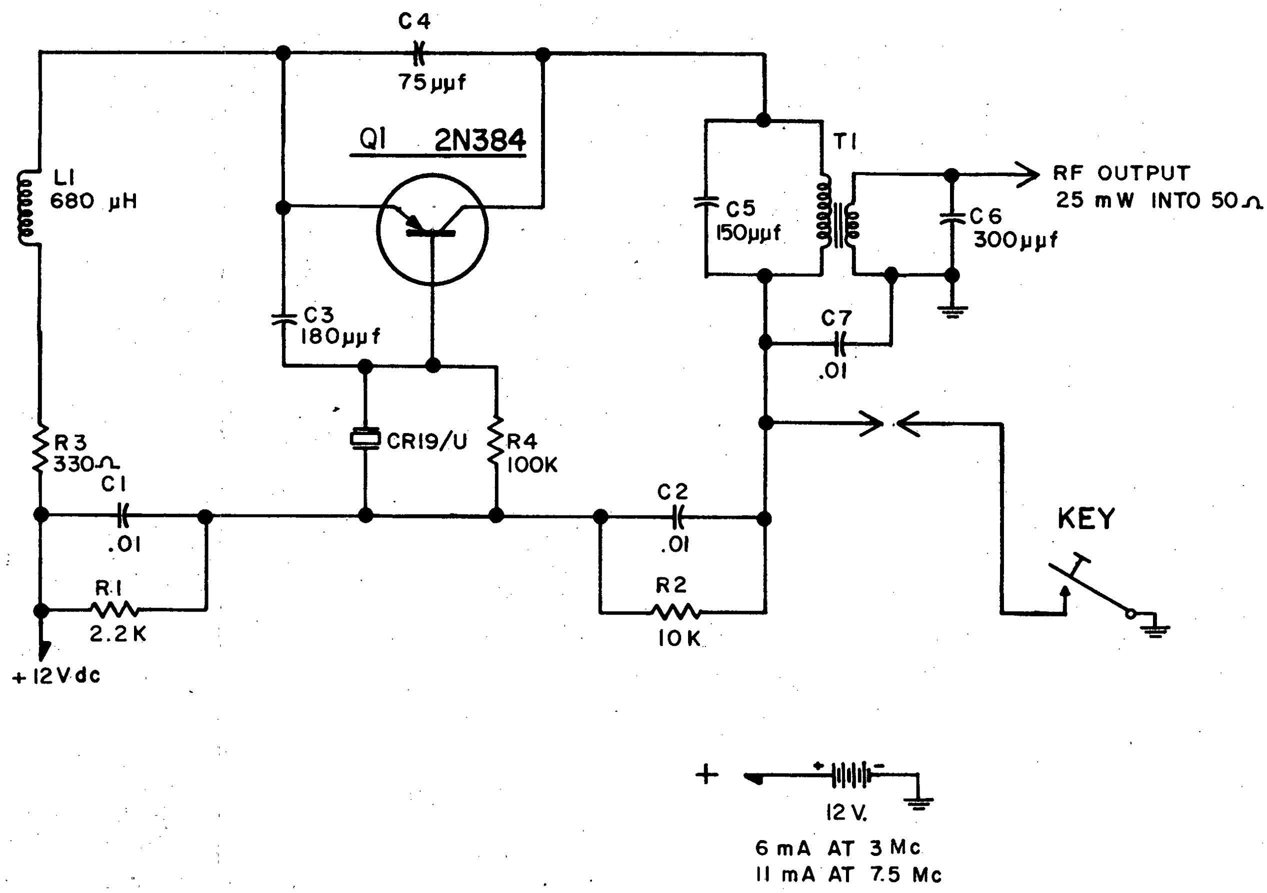


FIGURE 1

3—7.5 MC. TRANSISTOR R F OSCILLATOR

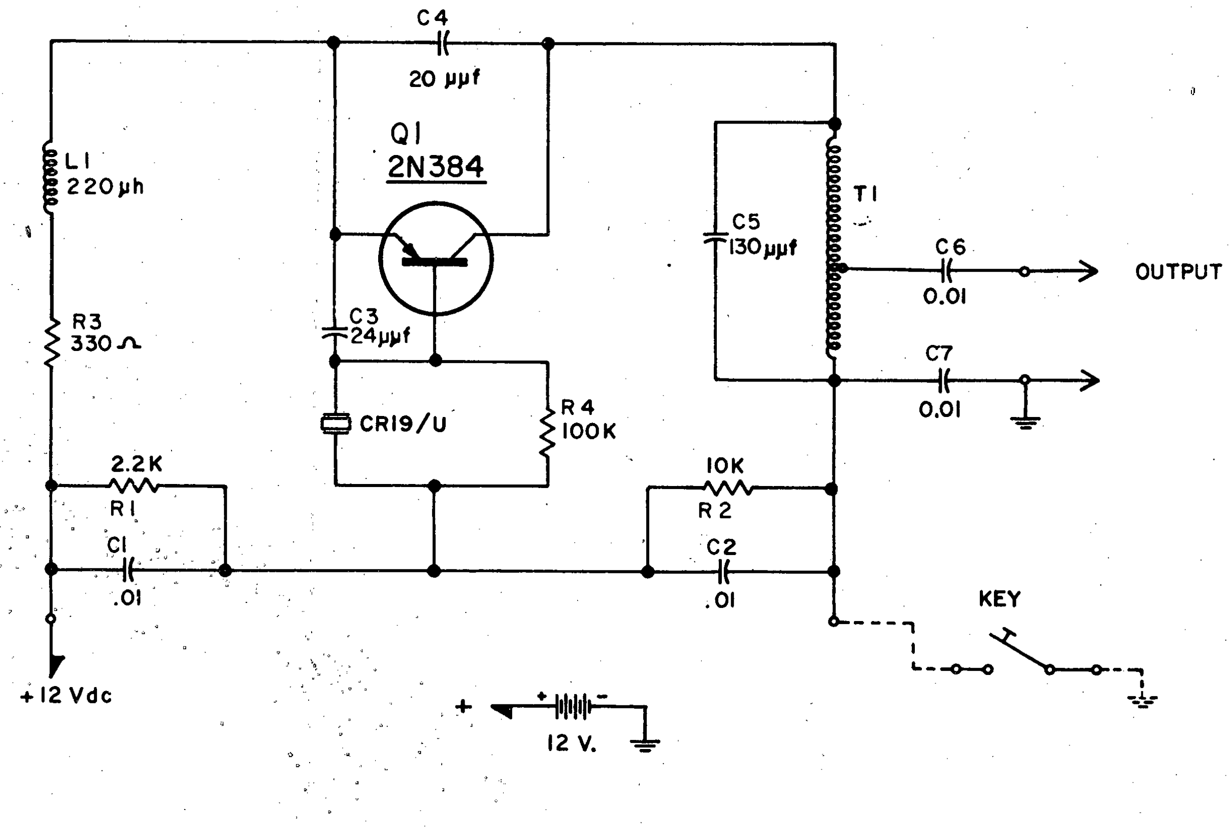
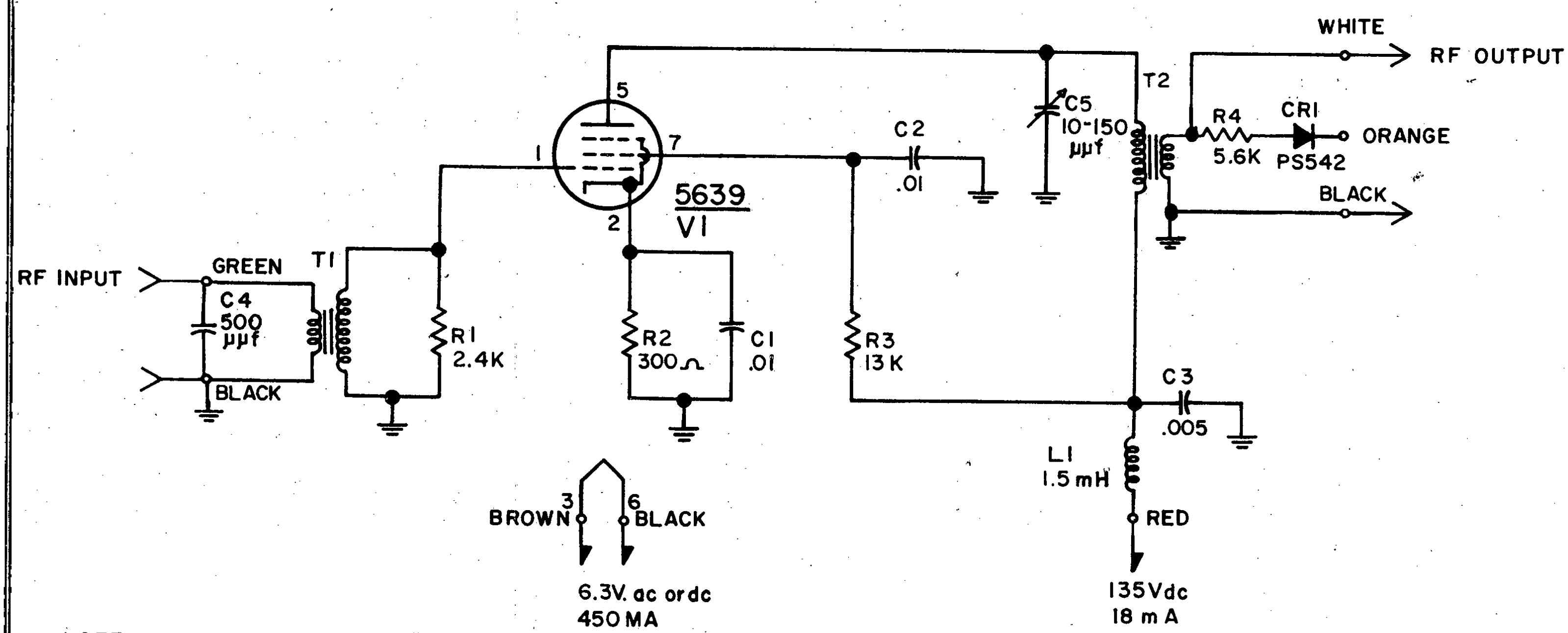


FIGURE 2
7.5 – 15 MC. TRANSISTOR R F OSCILLATOR



NOTE: ORANGE IS FOR HEADSET CONNECTION FOR MONITORING A2 KEYING, AND A3 SPEECH.

FIGURE 3

RF AMPLIFIER FOR 1/2 WATT SYSTEM 3-7.5 MC BAND

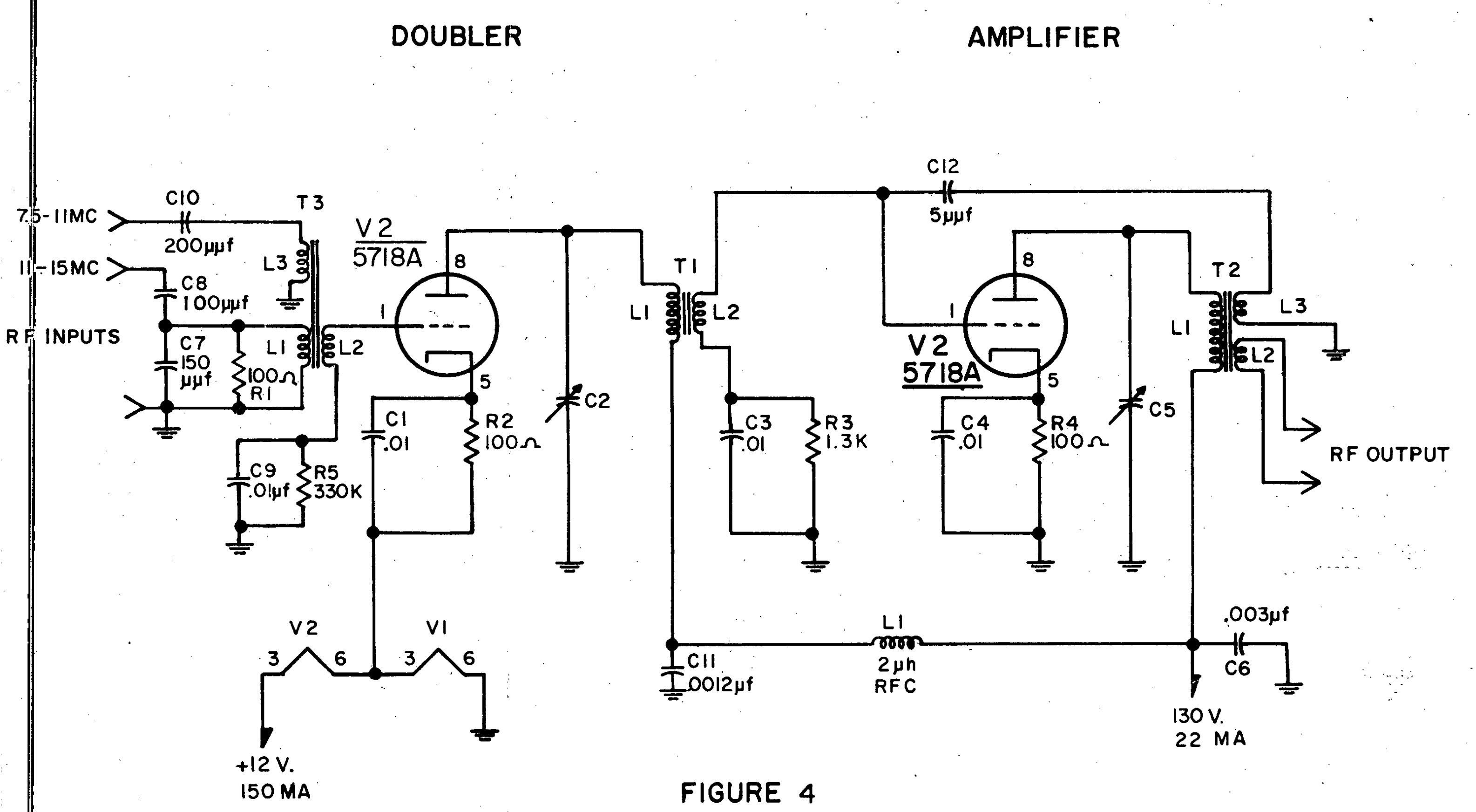
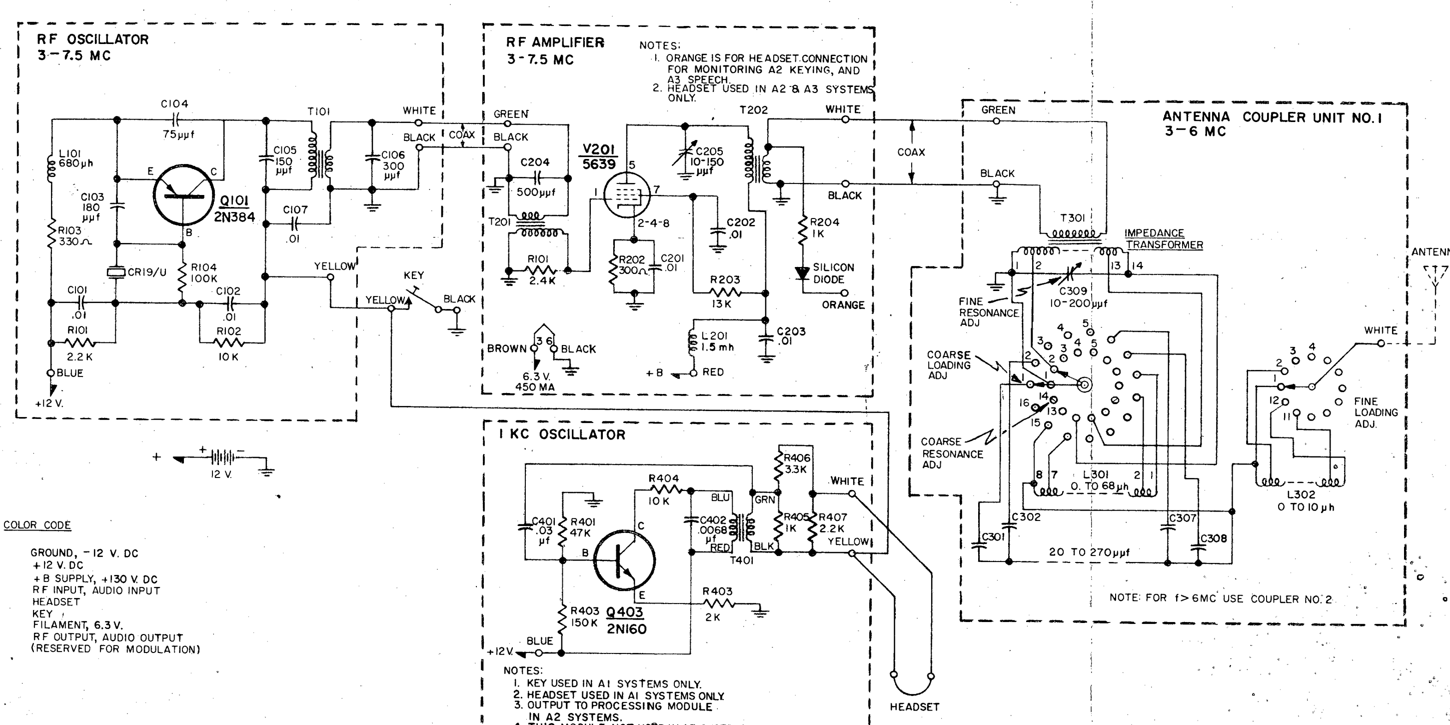


FIGURE 4
DOUBLER-AMPLIFIER 15-30MC BAND
1/2 WATT SYSTEM

200583

SYM	DESCRIPTION	DATE	APPROVAL

REVISIONS



NOTES:
1. ORANGE IS FOR HEADSET CONNECTION FOR MONITORING A2 KEYING, AND A3 SPEECH.
2. HEADSET USED IN A2 & A3 SYSTEMS ONLY.

COLOR CODE

BLACK	GROUND, -12 V. DC
BLUE	+12 V. DC
RED	+B SUPPLY, +130 V. DC
GREEN	RF INPUT, AUDIO INPUT
ORANGE	HEADSET
YELLOW	KEY
BROWN	FILAMENT, 6.3 V.
WHITE	RF OUTPUT, AUDIO OUTPUT
GRAY	(RESERVED FOR MODULATION)

NOTES:
1. KEY USED IN A1 SYSTEMS ONLY.
2. HEADSET USED IN A1 SYSTEMS ONLY.
3. OUTPUT TO PROCESSING MODULE IN A2 SYSTEMS.
4. THIS MODULE NOT USED IN A3 SYSTEMS

DO NOT SCALE DRAWING

FIGURE 5

MATERIAL:

FINISH:

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES.
TOLERANCES ON:
FRACTIONS ± 1/64
DECIMALS ± .005
ANGLES ± 0° 30'
REMOVE ALL BURRS AND SHARP EDGES.

SIGNATURE	DATE
	3/31/58
CHK.	
ENGR.	
APPD.	
SCALE	

BASIC
TYPE A-1 1/2 WATT SYSTEM
SCHEMATIC & WIRING DIAGRAM

PROJECT: 566-03

200583

50X1
50X1

109 Muth 1000H

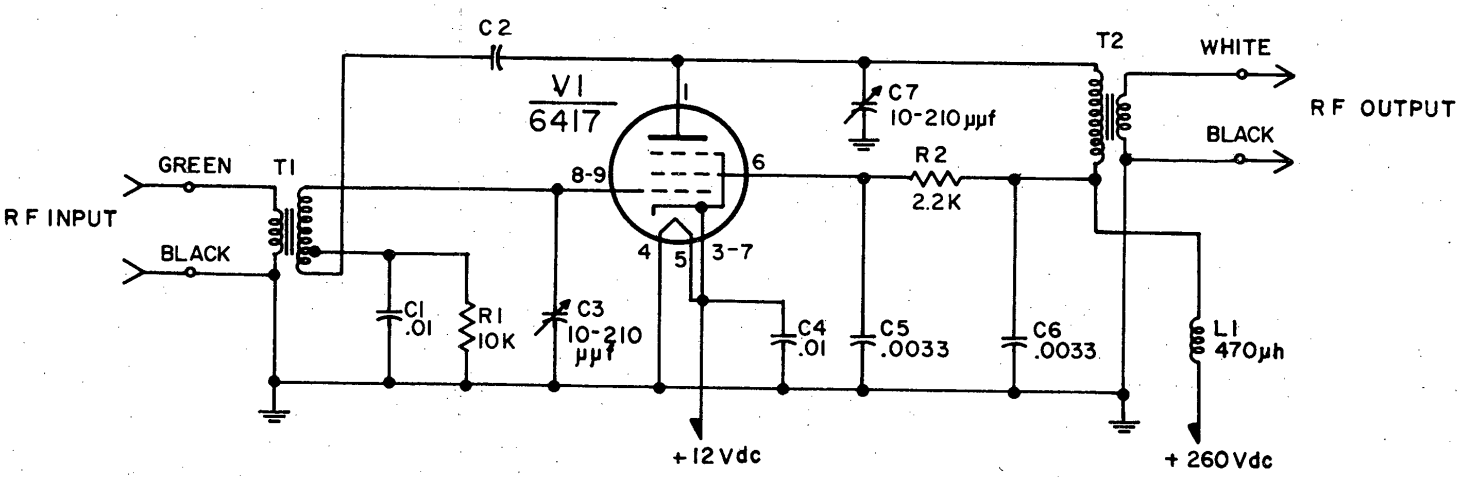


FIGURE 6

3-7.5 MC R F AMPLIFIER FOR 5 WATT SYSTEMS

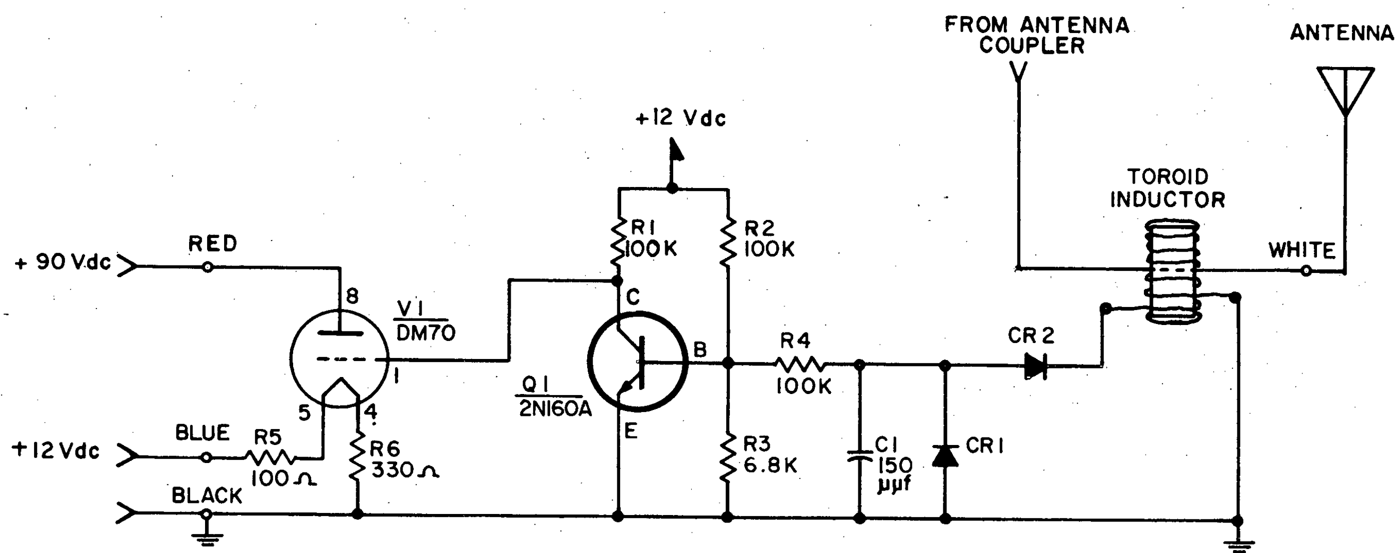
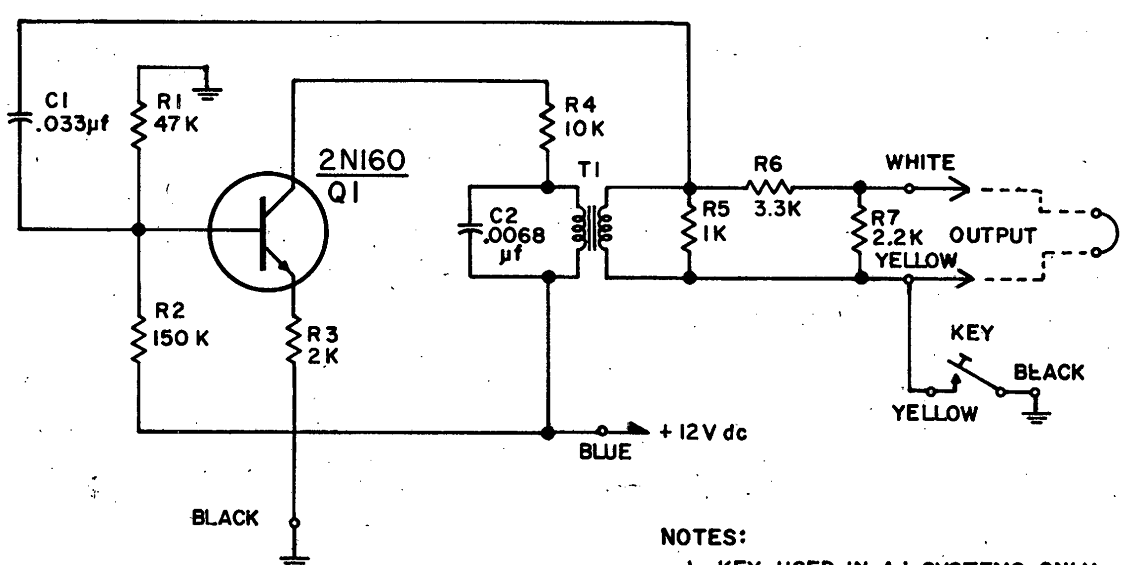


FIGURE 7
ANTENNA LOADING INDICATOR



NOTES:
1. KEY USED IN A1 SYSTEMS ONLY.
2. HEADSET USED IN A1 SYSTEMS ONLY.
3. OUTPUT TO PROCESSING MODULE IN A2 SYSTEMS.
4. THIS MODULE NOT USED IN A3 SYSTEMS.

FIGURE 8
1 KC OSCILLATOR

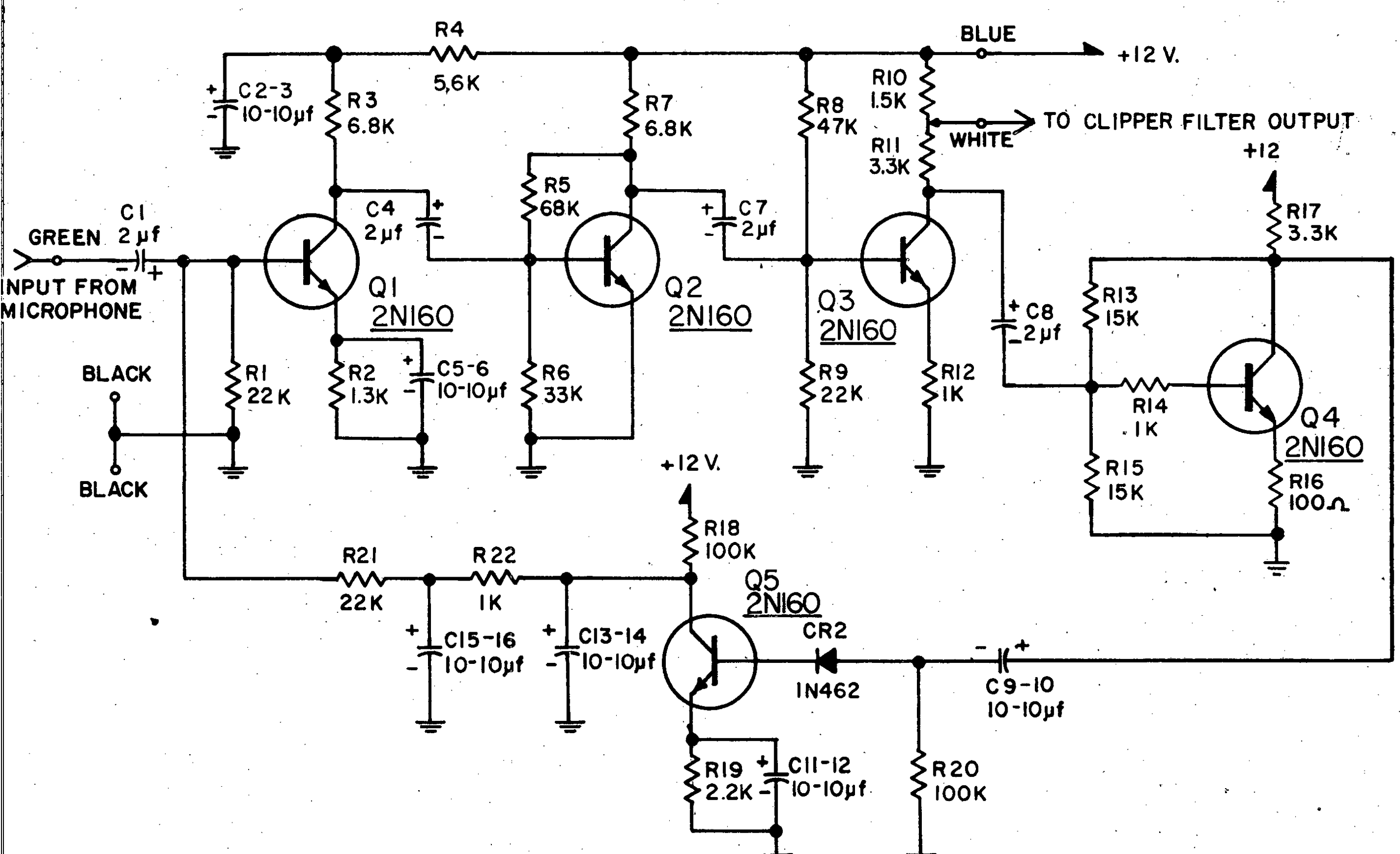


FIGURE 9
MICROPHONE PRE-AMPLIFIER

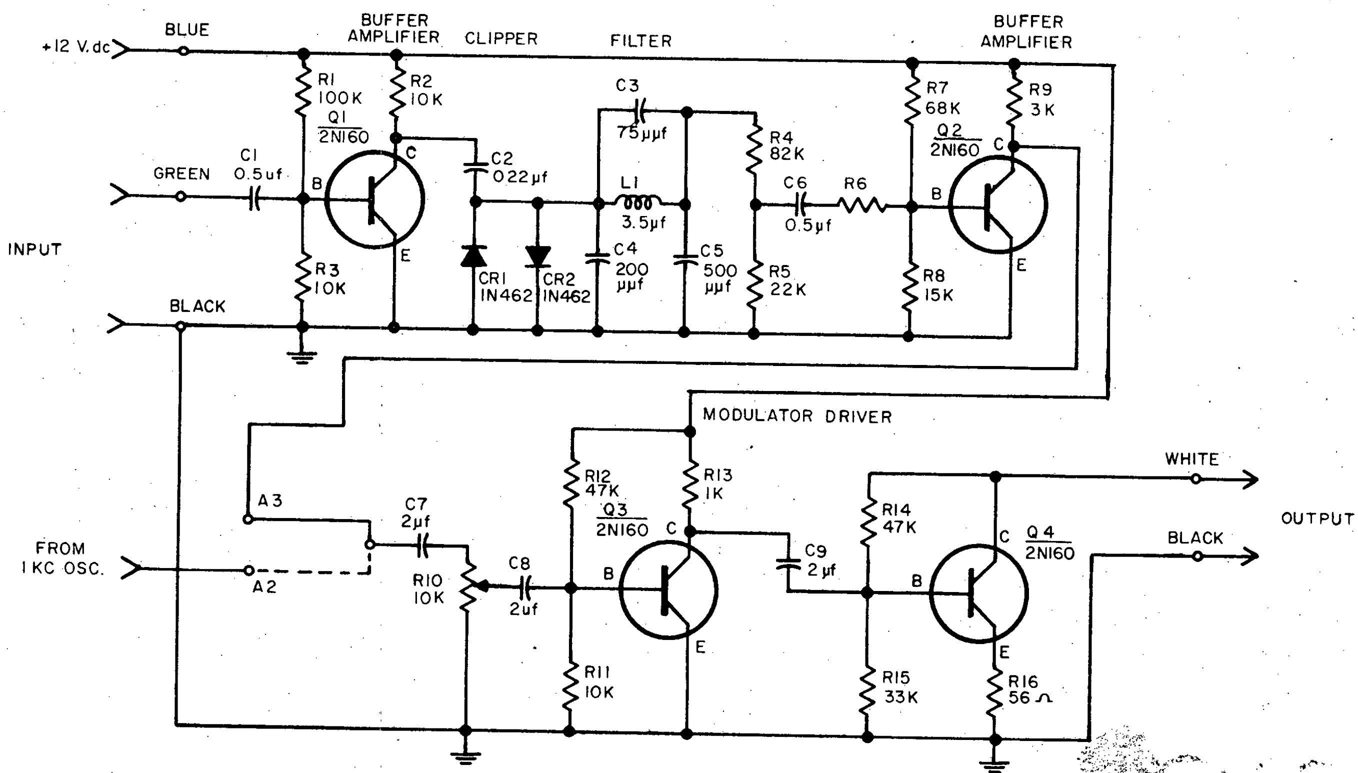


FIGURE 10
PROCESSING MODULE

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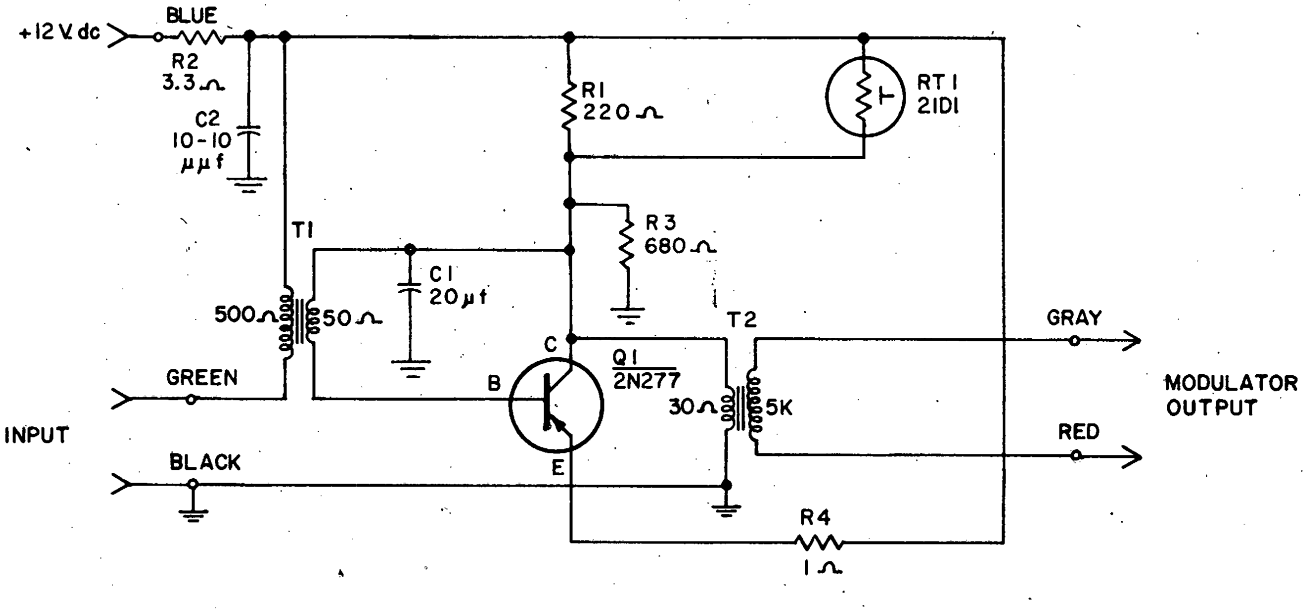


FIGURE 11

MODULATOR AMPLIFIER FOR 1/2 WATT SYSTEMS

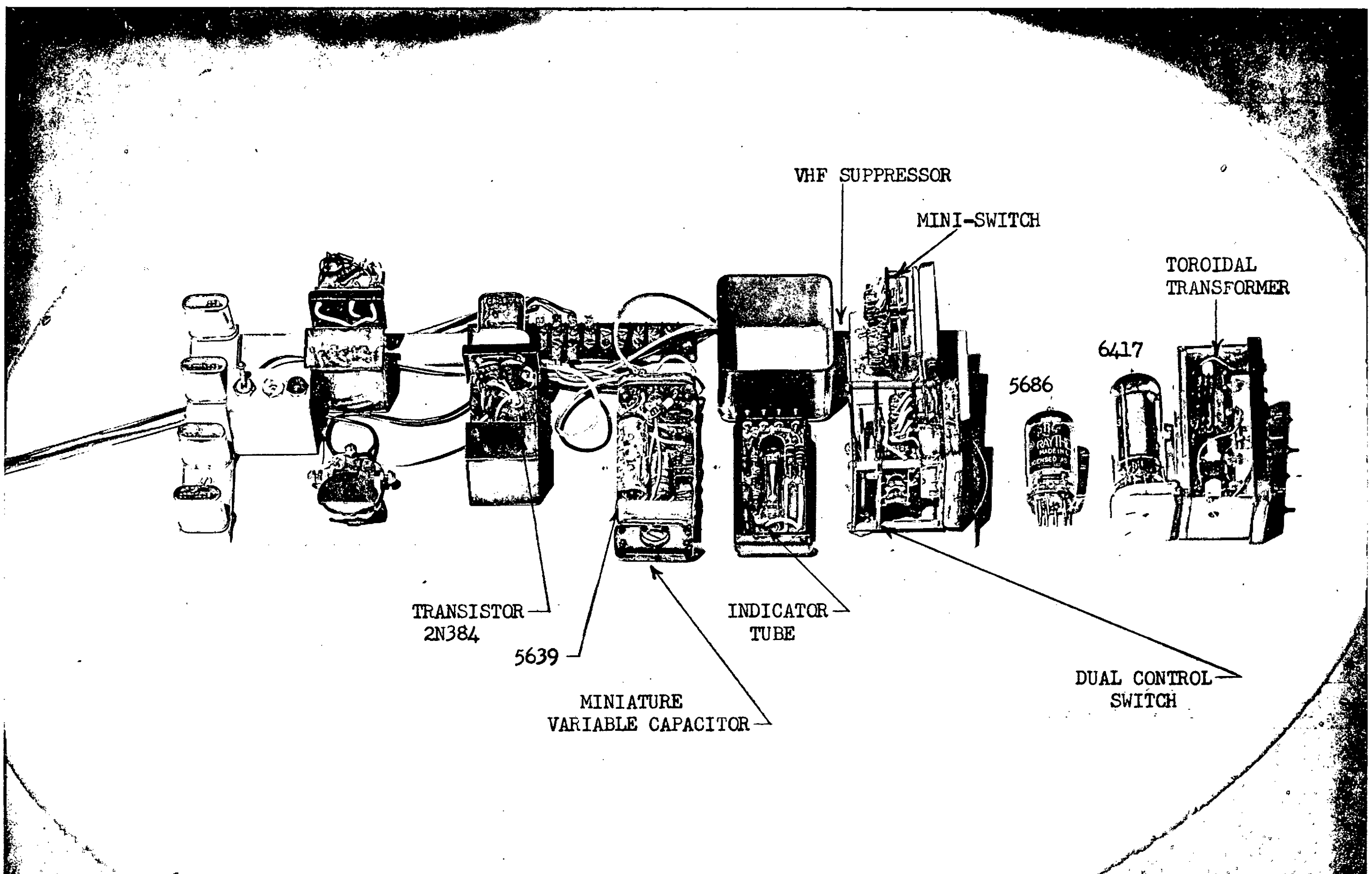


FIG. 12 3 TO 7.5 MC RF SECTION FOR THE 1/2 WATT OR 5 WATT SYSTEMS
(OPEN MODULE VIEW)

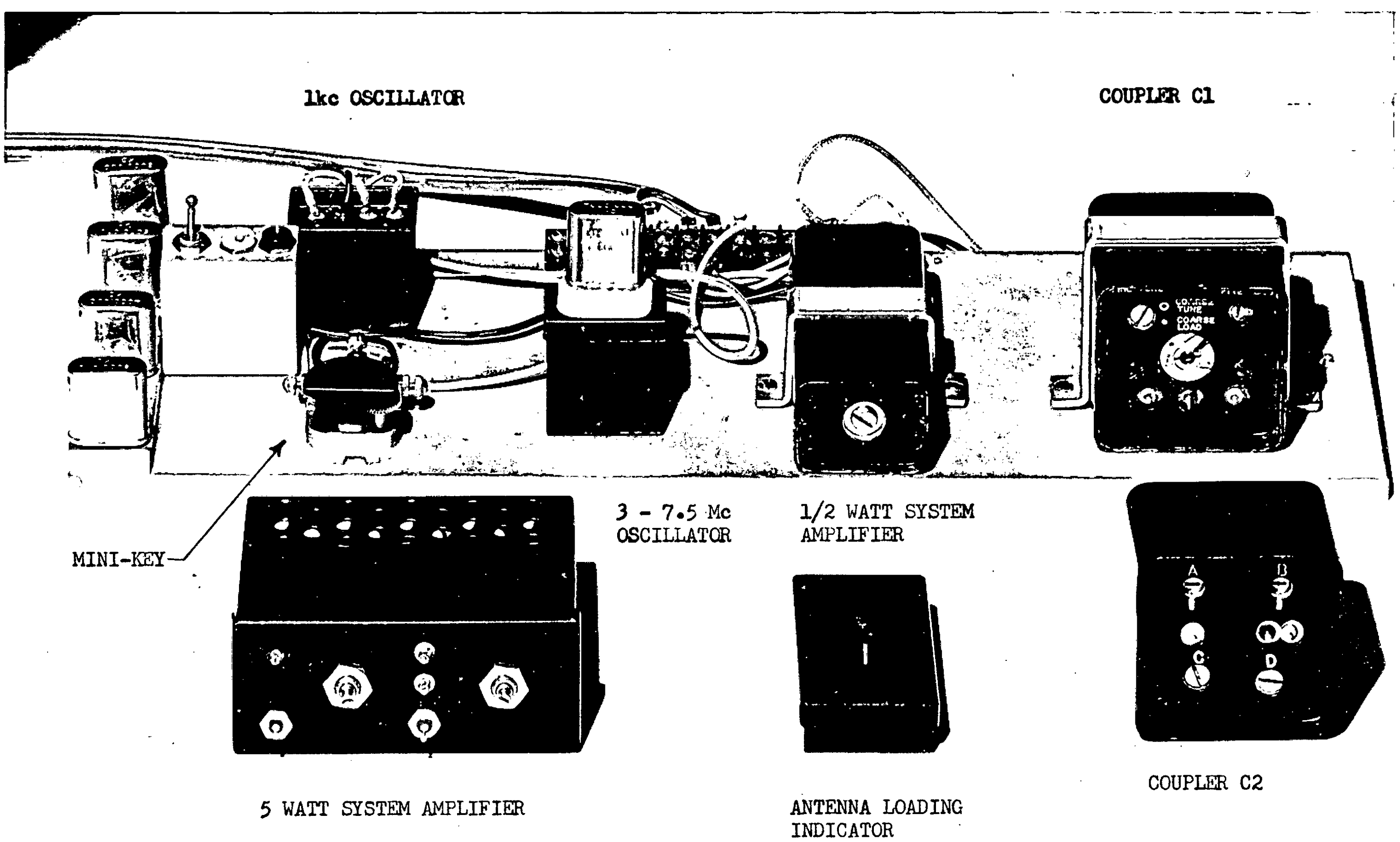


FIG. 13 3 TO 7.5 MC RF SECTION FOR THE 1/2 WATT OR 5 WATT SYSTEMS
(CLOSED MODULE VIEW)

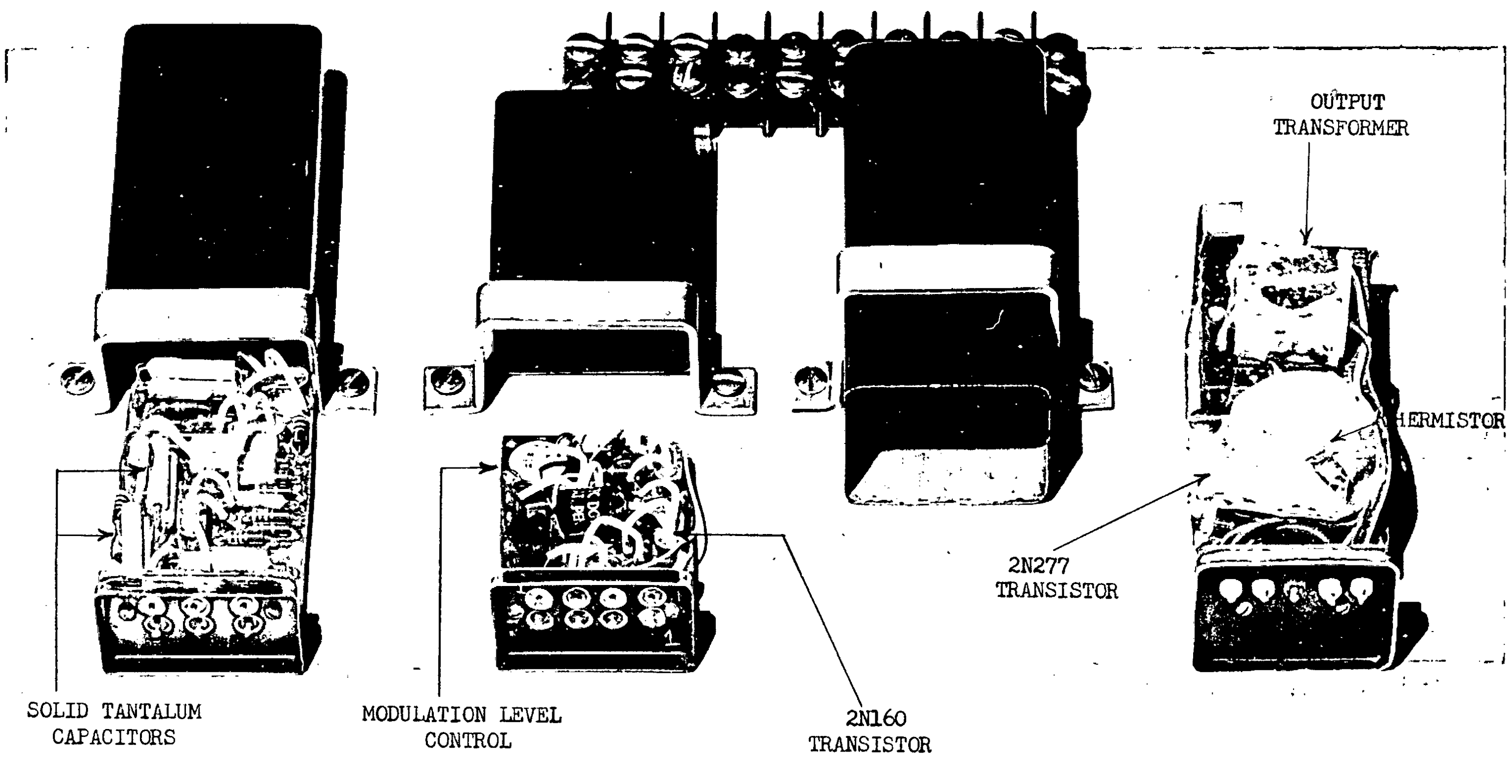
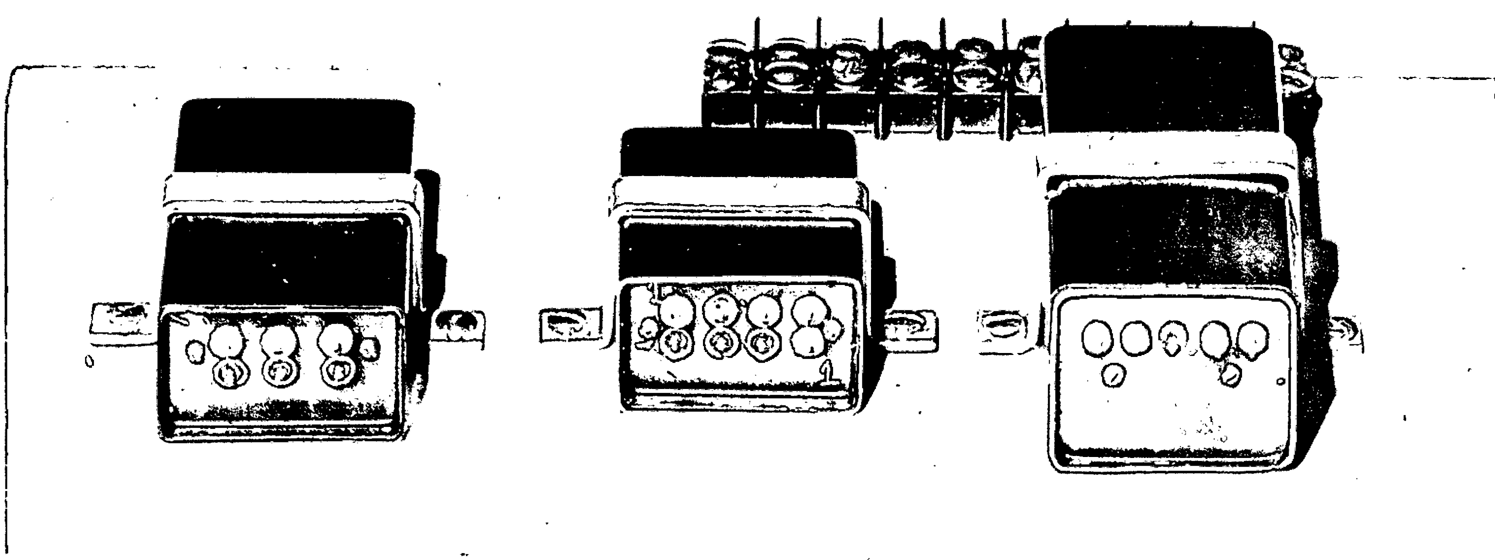


FIG. 14 MODULATOR FOR THE 1/2 WATT SYSTEMS (OPEN MODULE VIEW)



MICROPHONE
AMPLIFIER

PROCESSING
MODULE

1/2 WATT SYSTEM
MODULATOR AMPLIFIER

FIG. 15 MODULATOR FOR THE 1/2 WATT SYSTEMS (CLOSED MODULE VIEW)